THE

ANATOMY

OF THE

MADREPORARIA.

II.

INAUGURAL-DISSERTATION

DER HOHEN PHILOSOPHISCHEN FACULTÄT
DER UNIVERSITÄT LEIPZIG
ZUR ERLANGUNG DER DOKTORWÜRDE
EINGEREICHT.

VON G. HERBERT FOWLER, B.A.OXON.,
BERKELEY FELLOW OF THE OWENS COLLEGE, MANCHESTER.

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The Anatomy of the Madreporaria: II.*

By

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With Plate.

In a previous paper (4), I have described the anatomy of a solitary Imperforate coral, Flabellum; and of a branching Perforate, Rhodopsammia. The present memoir treats of two examples of colonial Perforate forms, Madrepora Durvillei and M. aspera.

Madrepora Durvillei (Milne-Edw. and Haime).

Two fragments of this perforate Madreporarian were kindly entrusted to me for study by Professor H. N. Moseley, who had obtained them during the voyage of H.M.S. "Challenger."

The species was founded by Milne-Edwards (1) from a part of the M. rosea of Esper, but as his account is very incomplete, Mr. J. J. Quelch, of the British Museum, has furnished the following description of the coral. I am glad to be able to take occasion to thank him for this and many other courtesies.

A. "**Corallum** arborescent, spreading, and remotely ramose, or occasionally sub-prostrate, and almost destitute of branchlets on the under surface. Branches often nearly 2 cm. thick, becoming very thin towards their extremity, subterete, elongated, covered irregularly with crowded capillary polyp-bearing branchlets, which generally give to the branches a sub-cylindrical outline of about 3—5 mm. in diameter.

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Branchlets small and short, about 1—2 cm. in length, consisting generally of a few thin and long tubiform calicles; towards the apical parts of the branches they become much less elongated and often quite short. Surface slightly porous, very distinctly costulated throughout, and marked with fine echinulations which are very distinctly arranged on the calicles. Calicles generally tubiform, about 1·5 mm. wide and 1· cm. long, except towards the apical parts of the branches, where they are shorter and smaller, and sometimes tubonariform; a few short tubonariform calicles are generally placed on the surface of the branches between the branchlets. Star distinct, of six more or less lamelli-spiniform septa, two of which, the distal and the proximal, are usually much enlarged, and meet one another, often deep down in the fossa; while occasionally, as in the terminal calicles, the six septa are subequal, and coalesce at the centre."

"This species seems to be distinguishable from the M. echinata (Dana) simply by the costulations of the surface, which in the latter is smooth or finely granulated. It is doubtful, however, whether this character will prove to be sufficiently constant to separate the two species, when a larger number of forms has been examined."

Figs. 1 and 2 represent the dorsal and ventral aspects of a fragment of a branch, and show most of the characteristics mentioned in the above description.

In a transverse section of the corallum (fig. 3), the peripheral ring of polyp cavities is cut somewhat obliquely (*a a.*), owing to the inclination of branchlets and calicles to the branch; while the more central ones, cut at a lower level and more transversely, are approximately circular in outline (*a' a'.*). They lie, roughly speaking, on three sides of the branch, none are apparent on the fourth. The shorter radius of the latter seems to imply that the growth in diameter of the branch depends upon the outward growth of the polyps.

In the axis of the branch is a central cavity (*c. c.*), into which project six septum-like ridges; this probably represents a cavity previously inhabited by the now apical polyp. The

tops of both my specimens having been broken off, I have not been able to prove this; nor again to investigate the method of budding; but in M. aspera is such another central cavity with six septa, which is continuous with that of the apical polyp. All other polyp cavities converge towards, and, by means of canals, eventually open into, this central cavity, but no more definite connection is traceable. Tissues not unlike mesenteries are sometimes visible in it, but the alcohol in which the specimens were killed did not penetrate sufficiently rapidly to preserve the central parts in good histological condition. In some sections the six septa are not recognisable, and the axis of the branch is occupied by a wide-meshed network of coral; this is probably due to reabsorption of part of the skeleton.

In transverse section are also seen concentric series of longitudinal canals (c^2.) permeating the corallum; their arrangement appears to indicate that the radial growth of the branch is effected in the following manner. Directly beneath the external body wall of the colony a series of longitudinal canals runs between the costæ (fig. 4, c^1); and it is probable that, for increase in the diameter of the branch, the costæ grow outwards, and then, bulging laterally, fuse over these canals, so as to enclose them entirely in corallum (*cf.* fig. 10, *x*.). Thus there results a series of internal longitudinal canals, concentrically arranged, with radii of coral between them which represent former costæ. Not only does the appearance of such a transverse section as fig. 3 suggest that this is the mode of growth, but also "dark lines of growth" (fig. 5) run radially from each costa towards the centre, so continuously as to indicate that what was a costa when the diameter of the branch was very small, has continued to grow as such, and to be still such, when the diameter is very much larger. New costæ, when required owing to the increased circumference of the branch, appear to take their origin from the point of fusion of previous costæ.

More minutely, growth is effected, presumably by the activity of calycoblast cells, through the addition to and formation of crystalline ellipsoids, similar to those described

by v. Koch in Stylophora (2). These ellipsoids have a distinct sweep from one "line of growth" to the next.

The calyces are all of approximately the same size, and that so minute as to render investigation of the anatomy difficult.

The septa are very irregular of occurrence; the complete number appears to be six, but three are rarely to be seen in one section, often none at all. They are not constant through the whole depth of the polyp cavity, but occur as discontinuous ridges (fig. 6, *Ab.*). In every polyp, however, either an axial or abaxial septum is present, which enables the orientation of the polyp to be effected as in the Alcyonaria. (These terms, axial and abaxial, are used in preference to the ordinary and misleading "dorsal" and "ventral," and were suggested originally by Professor Milnes Marshall, 'Trans. Roy. Soc. Edin.,' 1883.)

There is no columella, but often the axial and abaxial septa fuse, low down in the polyp cavity, so as to divide it into two equal halves (fig. 3, *a'*), in a manner suggestive of the "median plate" in Pocillopora and Seriatopora figured by Professor Moseley (3).

The costæ bear apparently no relation to the septa in the well-grown colony, whatever may have been the case in the founder-polyp. Not only is no connection traceable between them in a transverse section of the branch, but even in a single polyp standing off from the stem, where the number of septa is under the most favorable conditions but six, about twenty costæ surround the calicle.

B. **Anatomy.**—The whole of the corallum is covered externally by a definite body wall of ectoderm, mesoderm, and endoderm (fig. 6, *ext. b. w.*, fig. 4, *ect. me. en.*), immediately beneath which lie, as in Rhodopsammia, external longitudinal canals parallel to the long axis of the corallum (figs. 3, 4, 6, c^1). These, however, are not the result of the same anatomical relations in both cases; in Rhodopsammia, lamellæ of mesoderm with a layer of endoderm on each side are given off from the external body wall, and unite with the endoderm

and mesoderm which clothe the exterior surface of the theca; and into the canals thus formed project the costæ. In M. Durvillei, the layer of endoderm and mesoderm which is immediately apposed to the exterior surface of the corallum, rises in a ridge towards the external body wall; and at the points where these layers meet and fuse are formed the costæ, i.e. in the angle of the mesoderm; and therefore between the costæ lie the canals. A comparison of fig. 4 with (4) fig. 17 will make clear the anatomical difference.

There is thus no trace of any structure resembling the "peripheral continuations of the mesenteries of v. Koch."

These canals appear to open over the lip of the calyces into the polyp cavities; they are connected with each other transversely between the spikes (echinulations) of the costæ (figs. 6, 7); and further, by radial canals (figs. 3, 4, c^3.) they open into the internal longitudinal canals, which I believe, as above stated, to have, at an earlier period in the history of the branch, occupied a position similarly external to the corallum. The whole system which thus perforates the corallum, and allows free current of fluid to even the most remote parts of the colony, is lined by endoderm and mesoderm throughout, and opens into similarly lined polyp cavities.

The general structure of the colony is, therefore, (1) an external body wall, under which and between the costæ lies (2) a series of external longitudinal canals opening into each other, and also through the corallum, into (3) the internal canals, mainly longitudinal, with radial and transverse connections, communicating in their turn with (4) the cœlentera of the polyps. Into the last the external longitudinal canals also open directly, through the theca. The whole system is of course merely a complication of the primitive cœlenteron.

Of the polyps there are at least two distinct types, which are full of interest as constituting the first record of marked dimorphism among the Madreporaria. Both are Actinian in structure.

Type A has in the highest sections twelve perfectly normal

mesenteries, and a stomatodæum which is a simple invagination of the external body wall. A little way down in the polyp, six of the mesenteries, in every case the same six, assume a curious modification of structure, which will be described first as seen in a series of transverse sections. Fig. 8 represents the characteristic features of a polyp of this type; the mesenteries numbered 2, 4, 6, 7, 9, 11 are those which undergo modification, and are diagrams of a series of drawings made from the same mesentery with camera lucida at different heights.

There appears first (fig. 8.2) an involution of the stomatodæum directed towards the mesentery, on the floor of which the ectodermic cells are long, but shorter at the sides. By fusion of the mesoderm and obliteration of the ectoderm on each side of this involution, a small canal with a definite lumen is found to be pinched off, and to lie enclosed in the mesoderm lamella of the mesentery (fig. 8.4). In the neighbourhood of this involution, the endodermic cells lining the mesenterial chamber become enormously lengthened and vacuolated, though the layer is still apparently only one cell deep.

Some sections lower down in the polyp (fig. 8), another similar involution appears in the stomatodæum, in which the ectodermic cells are short on the floor, but pass into deeper ones at the sides; this similarly results in the enclosure of what appears to be a second canal in the centre of the mesentery (fig. 8.7). In the first canal, as is shown in the diagram, the longer ectoderm cells face towards the stomatodæum; in the second away from it.

Further down yet, where the stomatodæum ceases, the free edge of the mesentery is enlarged into a perfectly normal filament (fig. 8.9); and finally (fig. 8.11), the whole modification disappears suddenly, the two canals meeting below; the mesentery then presents a perfectly normal appearance, namely, a mesoderm lamella with a layer of small endodermic cubical cells on each side of it, and bearing the usual filament.

The compilation of these sections, which I have attempted to express in fig. 6 M, shows that on an ordinary mesentery

occurs a swelling due to elongation of the endoderm cells, through which runs, in the mesoderm, a canal lined by ectoderm, doubled back on itself, and opening at both ends into the stomatodæum, with the ectoderm of which its lining is continuous.

Of twenty-one polyps examined, seven present this modification of six (and in all cases of the same six) mesenteries, namely, those numbered 2, 4, 6, 7, 9, 11, according to the method employed in the diagram; the other six mesenteries, 1, 3, 5, 8, 10, 12, and all the twelve mesenteries of the other polyps, are perfectly normal, and show no tendency to such a modification. Were it possible to explain the sectional appearances by a contortion of the mesentery, the regularity with which it occurs would be sufficient proof that it is a definite modification of structure, the parallel of which has yet to be sought in the Anthozoa.

The unmodified mesenteries in Type A, generally die out before the plane of the opening of stomatodæum into cœlenteron is reached, in transverse sections. If they present a filament, which is seldom the case, it is of the same character as that figured (fig. 8.11), i.e. identical with that of a modified mesentery; more frequently none is present, or at most a slight endodermal swelling on the free edge.

The mesenteries 4, 9, run very much deeper into the corallum than the others.

Type B, of about the same diameter as A, is of the normal Actinian structure. The twelve mesenteries are simple, and exactly like those unmodified in Type A. Most of them die out after a very short course, but those numbered 2, 4, 6, 7, 9, 11, on the same notation as in fig. 8, present a more developed filament than the other six, and extend further down into the corallum, and of these 4, 9, have by far the longest course, and are the only ones that bear ova.

We have thus two distinct types of polyp, the one distinguished only for entire normality; the other with a hitherto undescribed form of mesentery. In both is observable a differentiation affecting the same six mesenteries, exhibited in the

one case as a tendency to a longer course, and to the more complete development of the filament; in the other as the peculiar modification described above; and in both types two of these six have of all the longest course, and are, so far as I have observed, the only ones that bear reproductive organs.

Neither type is confined to certain areas of the branch, but both appear to be irregularly distributed.

Tentacles are not recognisable in my specimens, but it is probable that in the living animal they occur as slight evaginations of the chambers, and have shrunk under the action of the alcohol in which the polyps were killed.

Muscles are obviously present on the mesoderm lamella of the mesenteries, but owing to their minute size it is impossible to detect how they are arranged. I see no reason to doubt that they agree with Actinia. So far as it is possible to judge without this clue, the septa are entocœlic.

c. **Histology.**—There is but little to be said under this head, except as regards the modified mesentery, an almost transverse section of which is represented in fig. 9. The state of the specimens did not allow of an exhaustive study of cell structure, but those cells, the elongation of which causes the peculiar swelling on both surfaces of the mesentery, are apparently simply lengthened, much vacuolated, and amœboid at their free ends. No food particles were detected in them, or indeed in any other part, but many zooxanthellæ are embedded amongst them. These cells pass gradually into the ordinary endoderm, and their appearance suggests strongly that their condition is merely an exaggeration of that of the "Flimmerstreifen" of the brothers Hertwig, i. e. of the two lateral lobes of the mesenterial filament.

In a recent paper (5) Dr. Wilson has suggested that these lateral lobes are ectodermic in origin, circulatory in function, and homologous with the "ectodermic bands" described by him on the axial mesenteries of certain Alcyonaria. I may here state that, so far as histological evidence from the adult is valuable, it points, in all the Madreporaria that I have yet examined, distinctly in the other direction. The central

"Nesseldrüsenstreifen" have precisely the same microscopic appearance as the stomatodæal ectoderm; while the "Flimmerstreifen," in the unbroken gradation by which they pass into the endoderm, and by their characteristic staining, seem to be much more nearly connected with that layer than with the ectoderm, and to exhibit an intermediate condition between the ordinary cubical or pavement cells of the endoderm and the enormously lengthened cells of M. Durvillei. v. Heider (6), on the same grounds, had previously come to the same conclusion with regard to Cerianthus.

The ova, which in my specimens were few in number, are surrounded by a mesodermal capsule, and possess the ordinary structure. In the one case, in which an ovum was observed on a modified mesentery, it was borne on the neck between the endodermic swelling and the mesenterial filament.

D. General Conclusions. — This form has four interesting features in common with the Alcyonaria (Octactiniæ):

1. The marked tendency to an absence of polyps on one (the ventral) side of the branch and branchlets.

2. The very definite orientation of the polyps by a stronger development of axial and abaxial septa; and the concomitant bilateral symmetry, the plane of bisection being at right angles to the long axis of the branch or branchlet.

3. The differentiation of mesenteries, which, confined in the Alcyonaria to two, is here extended to six, and more particularly to two of these, though not the same two as in the other group.

4. The distinct dimorphism.

Of the true significance of this dimorphism no certain explanation can be gathered from this form studied merely by itself; it can only be resolved by a comparative study of allied species. Differentiation of function appears to be incomplete; both forms are reproductive, both apparently digestive. The most that can be said is that A is, perhaps, more digestive and less reproductive than B, for the filaments are more developed than in the latter form, and I have only once observed an ovum on a modified mesentery. Should the modification

be digestive in function, as is probably the case, A might certainly be termed a "gastrozooid."

But at present any explanation of the function of the structure above described, cannot be other than a mere speculation. It cannot be regarded as a necessary result of the colonial habit, since nothing similar occurs in the next species to be described—M. aspera. It can hardly be connected with reproduction, as ova are of rarer occurrence in the modified than in the unmodified polyps; and an excretory apparatus is not required by an organism whose cells are capable of amœboid activity, egestion as well as ingestion.

The only evidence on the point is derived from the distribution of the zooxanthellæ. These are most plentiful, firstly, in the external canals just under the body wall; and secondly, among the elongated cells of the mesentery. Assuming, as we may fairly do, that nutriment and aëration were the determining factors of such distribution, it would seem that, in the first case, there must be a strong current of nutritive "chyle-aqueous fluid" (to use a word of the older zoologists) in these external canals, and that aëration was effected by diffusion of oxygen through the body wall from the surrounding medium; and in the second place, that the elongated vacuolated cells of the mesentery were in some way assimilative, while oxygenation of the tissues for these special digestive processes (and therefore secondarily and accidentally to the benefit of these symbiotic algæ), resulted from a constant stream of water flowing through the central ectodermal canal of the mesentery.

That such a stream does pass through this canal is extremely probable, for the longer ectodermic cells are all morphologically on the same side of the canal; a wave of ciliary action must therefore result in a current through the canal from one of the apertures into the stomatodæum towards the other. A comparison of fig. 8.7 with fig. 6 M will explain this arrangement of the cells.

It is interesting to note that in M. Durvillei, as in Alcyonaria and Antipatharia, two mesenteries are distinguished

from the rest by running far deeper into the corallum or rachis. This may be a specialisation for circulatory purposes, as has been shown by Dr. Wilson to be true for certain Alcyonaria, or connected with production of the generative elements, as is the case in Antipatharia; in M. Durvillei certainly the latter, perhaps also the former, holds good.

Madrepora aspera (Dana).

For a fragment of this coral, fortunately the upper part of a branch, I am again indebted to Professor Moseley.

The species was founded by Dana (7), who gives a good figure of the colony.

A. Corallum.—A transvers esection of the corallum (fig. 10) shows that the polyp cavities (*a a'*) are arranged in a definite ring, and not merely confined to three sides as in M. Durvillei, round a central cavity into which project six septa, more or less fused together at their free edges. This central cavity (*c. c.*) is continuous with that of the apical polyp of the branch. The arrangement of the internal longitudinal canals is not so definitely concentric as in M. Durvillei, but the method of circumferential growth of the corallum appears to be similar in both species, since the costæ appear to fuse over the external longitudinal canals (*v.* fig. 10, *x*, and p. 3).

In the apical polyps are found six distinct entocœlic septa, and six smaller exocœlic, of which all are not always present; in the others generally only an axial or abaxial septum. A similar difference between them was observed by v. Koch (8) in M. variabilis, where both exosepta and entosepta were present in the apical polyps, but entosepta only in the rest.

In this form, as in the former species, there appears to be no relation in number and position between costæ and septa, the former being by far the most numerous.

The costæ are apparently formed as in M. Durvillei, that is, at the points where the endoderm and mesoderm apposed to the exterior surface of the corallum touch the external body wall (*v.* p. 5 and fig. 4), but in both species, owing to alcoholic contraction, the latter has so shrunk on to

the corallum that the costæ project through it, and the exact conditions are difficult to determine with certainty.

B. **Anatomy.**—The general anatomy of the colony, as regards the relations of canals, body wall, polyp cavities, &c., agrees with that of M. Durvillei. Beyond the fact that in M. aspera the polyp cavities are placed closer together, and that therefore there are fewer canals in the corallum, there is little or no difference between them. As regards the polyps, however, there is no dimorphism; all the polyps, except those which are obviously immature buds, are identical in structure.

A typical polyp possesses twelve perfectly normal mesenteries, and a stomatodæum which is a simple invagination of the external body wall. When numbered on the same system as in M. Durvillei, it is found that those mesenteries marked 1, 2, 4, 6, 7, 9, 11, 12, are the ones which develop mesenterial filaments, that is, the same mesenteries as in M. Durvillei, with the addition of the abaxial "directives;" while the others, 3, 5, 8, 10, generally have no filament, and do not extend to the bottom of the stomatodæum.

The apical polyps are about twice the size of the others, but, except for their possession of more septa, are identical in structure with them.

The muscles in both apical and lateral polyps are arranged on the mesenteries just as in Actinia, and present nothing unusual in structure.

Tentacles I was unable to recognise, macroscopically or by sections, but a figure by Dana shows that they are present, and twelve in number. In this, as in the species last described, they have shrunk into insignificance, owing to the action of the spirit in which the specimens were preserved. They agree with M. variabilis, in which, according to v. Koch, they are also exocœlic and entocœlic.

The histology calls for no remark, agreeing with that of forms already described. Calycoblasts were very distinctly present in the growing parts of the colony.

C. **Method of Budding.**—With regard to this, I have been able to glean but little information; since the immature polyps

are so crowded with zooxanthellæ, owing presumably to the amount of nutriment supplied to them, that the tissues are much obscured.

The stomatodæum is invaginated to a considerable depth into the future polyp cavity before it is perforated for communication between the cœlenteron and the exterior, and also apparently before any mesenteries are formed. The cavity into which it is invaginated is already of considerable diameter, and larger than the ordinary canals of the colony; though smaller than that of a fully formed polyp, at that point it is probably never enlarged by reabsorption of coral, but its continuation upwards by future growth of the polyp possesses a gradually increasing diameter.

In a young polyp in which the stomatodæum was invaginated, but not yet perforated below, the latter appeared to be supported by tissue surrounding the future septa, just as the external body wall is supported by tissue enclosing the costæ. In sections below the stomatodæum, and unconnected with it, were seen two small mesenteries with filaments, which appeared to be growing upwards towards the stomatodæum, and to have not yet joined it. It is therefore possible that these grow upwards from the canal system, and are formed quite independently of the rest of the polyp. This view is further supported by the observation that, in sections quite at the top of a branch, above the plane of any lateral polyps, occur in the canals one, sometimes two, little mesenteries with filaments, which I believe to be growing upwards towards the sites of future polyps. They appear to take rise, near the cavity of the apical polyp, from the wall of the canals.

In the only other stage of development from which any observations could be made six mesenteries had appeared; of these the two furthest from the axis carried muscles on the outer faces, though it does not necessarily follow that they were the abaxial "directives" of the adult. The muscles of the other two pairs were not sufficiently developed to allow of their arrangement being recognised.

Conclusion.—From M. Durvillei, the present species is

widely separated by a strong morphological distinction, the absence of dimorphism; since the difference between the apical and lateral polyps in M. aspera is hardly strong enough to be reckoned as such. That such a distinction should exist between two species of a genus is very remarkable; but, considering the great antiquity of these forms, the similar structure of the colony in both, and the fact that they exhibit a similar differentiation of certain mesenteries, it is not to be inferred that their systematic relations are unsound.

Note.

For microscopic sections through both hard and soft parts of the coral, such as are figured in (4) Pl. XLI, figs. 14, 15, I have found the method, originally applied by v. Koch to these forms, extremely useful. The coral, having been left in borax carmine for three days, and treated with acidulated alcohol for six hours, is transferred to absolute alcohol, and from this to ether; into the ether is dropped absolutely dry powdered Canada balsam in small quantities at a time, till enough is dissolved to make a block, rather larger when dry than the specimen. The ether is driven off by a gentle heat, leaving the coral permeated throughout by balsam. About a week should be devoted to this part of the process.

Sections are then cut with a lapidary wheel, or, if this is not procurable, with a fret saw; and ground like geological sections on a slate, then polished on a water of Ayr stone. Oil and emery powder should be avoided, water alone being used for the stones.

One surface of the section having been ground and polished, it should be affixed permanently by that surface to a glass slide, on to which some dry Canada balsam has been melted, and not again be moved. When the other surface has been similarly ground and polished to the required thinness, it should be brushed lightly, first with absolute alcohol, then immediately with oil of cloves; this removes all dirt from the surface. A drop of balsam in benzole is then placed on the section, and the cover glass lightly dropped on it.

Erratum.

In my previous paper (4) Pl. XL, fig. 1, the septa were wrongly numbered; they should have been marked 1, 4, 3, 4, 2, 4, 3, 4, 1, reckoning on each side from the central "directive" septum, D.

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VITA.

Ich, Georg Herbert Fowler, wurde in Lincoln, Sep. 4, 1861, als der Sohn eines Geistlichen der englischen Kirche geboren, und trat im Jahre 1876 als "King's Scholar" in Eton College ein. Ich wurde in der Universität Oxford, 1880, matriculirt, wo ich Naturwissenschaft, und vorzüglich Zoologie unter der Leitung von Prof. Moseley, Dr. Hickson, u. a. studirte und in letzterem Fache den Grad eines "Bachelor of Arts" mit Auszeichnung 1884 bekam. Im selben Jahre erhielt ich eine Anstellung als "Berkeley Fellow" an Owens College in Manchester, wo ich die betreffenden Untersuchungen über die Anatomie einiger Madreporarien die durch das Königl. engl. Schiff "Challenger" gesammelt wurden unter der Leitung von Prof. Milnes Marshall anstellte. Seit Mai, 1886, besuche ich als Hörer die Vorlesungen des Herrn Geh. Prof. Dr. Leuckart, in dessen Laboratorium ich weitere Forschungen ausführe.

DESCRIPTION OF PLATE.

a. Polyp cavities, cut obliquely. *a'*. Polyp cavities, cut transversely. *Ab*. Abaxial (ventral) septum. *Ax*. Axial (dorsal) septum. *C*. Costæ. *c. c*. Central cavity, continuous with the apical polyp. c^1. External longitudinal canals between the costæ. c^2. Internal longitudinal canals. c^3. Radial and transverse connecting canals. *Co*. Corallum of the main branch. *d*. Cut edges of the endoderm and mesoderm lining the cœlenteron. *ect*. Ectoderm. *en*. Endoderm. *ext. b. w*. External body wall of ectoderm, mesoderm, and endoderm. *M*. Mesentery, showing the endodermal swelling. *me*. Mesoderm lamella. *S*. Septum. *S. C*. Septal Columella-plate. *St*. Stomatodæum. *Th*. Theca of polyp. *Z*. Zooxanthellæ. *x*. Fusion of costæ over ext. long. canals. All except Fig. 10 are from Madrepora Durvillei.

Fig. 1.—Dorsal view of the corallum of two fragments of a branch, bearing calicles, and branchlets formed of other calicles.

Fig. 2.—Ventral view of the same specimens; one of which is entirely bare of calicles on this side, and on the other only a few are present.

Fig. 3.—Transverse section of a branch, showing the polyp cavities, the central cavity, and the canals running in various directions. The concentric arrangement of the latter is well shown. Into the central cavity project the six septa. In two of the innermost ring of polyps, the axial and abaxial septa have fused into the septal columella-plate.

Fig. 4.—Diagram of a transverse section of a polyp and of part of the branch. The external body wall is shown to be supported on the costæ, as its mesoderm and endoderm are continuous with those lying on the outer face of the corallum. The polyp cavity shows at this point twelve mesenteries supporting the stomatodæum. (In nature the mesoderm lies closely apposed to the surface of the corallum, and there is no space between them, such as is introduced into the diagram for clearness.)

Fig. 5.—Transverse section of a portion of the branch, to show the lines of growth, running between the canals radially and terminating each in a costa.

Fig. 6.—Diagram of a longitudinal section of a polyp along the dotted line in Fig. 8. The tentacles are omitted, as they were not recognisable in my specimens; the canal system in the corallum is also omitted. On the left the section passes between the axial septum and mesentery No. 7, and above the polyp down an external longitudinal canal; on the right, through the abaxial septum and down a costa, of which the echinulations and the canals between them are shown. The numbers indicate the same mesenteries as in Fig. 8. On the mesentery 7 is figured the endodermal swelling, with the bent canal

indicated by dotted lines. In the stomatodæum are shown the two openings of the canals of mesenteries 7, 9, 11; and below the stomatodæum the free edges of these three mesenteries alone appear, the others dying out before this plane is reached. The dotted line indicates the junction of theca and septa, and the discontinuous character of the septum (*Ab.*) is clearly shown.

Fig. 7.—The external body wall viewed from the exterior; the lighter spots are the places where the echinulations of the costæ have pierced the body wall on account of its shrinkage. This drawing shows the arrangement of the external longitudinal canals, and their connections between the spikes of the costæ. (Camera lucida.)

Fig. 8.—Diagram of the various forms and conditions of the mesenteries in a polyp of Type A. Those numbered 1, 3, 5, 8, 10, 12 are unmodified and normal. The others, 2, 4, 6, 7, 9, 11, are modified in all the polyps of this type; they are from camera lucida drawings of the same mesentery at different heights. The arrows and Roman numerals in Fig. 8 show the planes in which the successive sections are taken.—2 shows the endodermal swelling, and the upper opening of the canal; 6 shows the lower opening; 9 is below the stomatodæum, and bears a filament; and in 11 no trace of the modification remains, the mesentery being normal, and similar to those of Type B.

Fig. 9.—Transverse section of a modified mesentery, passing through both arms of the canal.

Fig. 10.—Transverse section of the corallum of a branch of M. aspera.

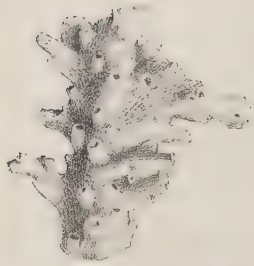


Fig. 1.
× 1 5

Fig. 4.
× 25.

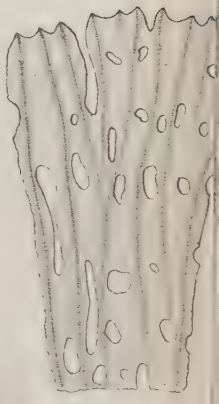


Fig. 5.
× 16.

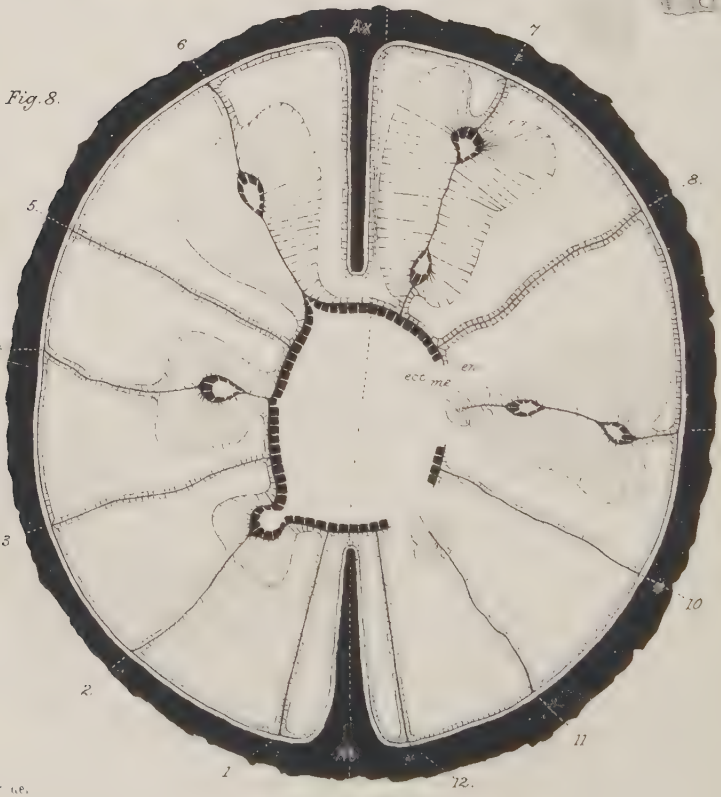


Fig. 8.

H Fowler ad.

Fig. 2.

X 1.5.

Fig. 3.

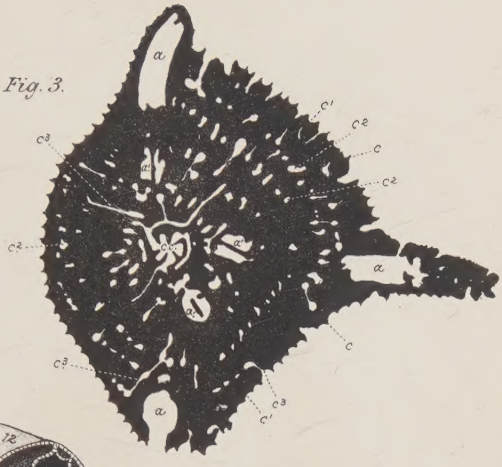


Fig. 6.

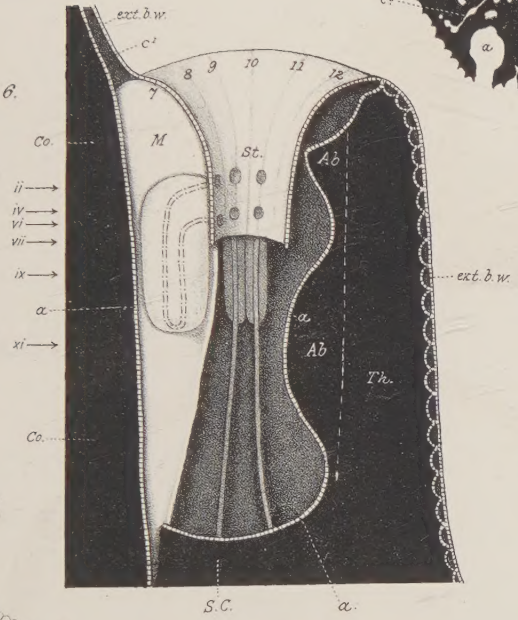
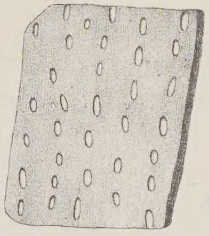


Fig. 7.



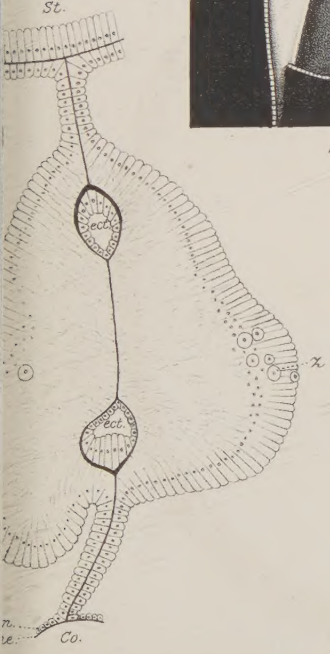


Fig. 10.

F. Huth, Lith^r Edin^r